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ASSESSMENT OF PELVIC ALIGNMENT IN STUDENTS USING THE DUOMETER

Katarzyna Barczyk-Pawelec[1 A, D-G]
• ORCID: 0000-0001-5745-4167

Jacek Rydzyk[B,C]

Arletta Hawrylak[1 G]
• ORCID: 0000-0002-2329-8941

[1] Council of the Faculty of Physiotherapy, Wroclaw University of Health and Sport Sciences, Poland

A – study design, **B** – data collection, **C** – statistical analysis, **D** – interpretation of data, **E** – manuscript preparation, **F** – literature review, **G** – sourcing of funding

ABSTRACT

Background: Previous methods used to assess the pelvis were based on visual and palpation assessment, which are characterized by low reliability. Research using a Duometer, an appropriate diagnostic tool for performing pelvic measurements, allows for a more accurate assessment of the pelvic girdle.

The aim of the study: The aim of the study was to assess pelvic position in students using the Duometer in the sagittal plane.

Material and methods: The study included 30 students, consisting of 15 women and 15 men aged 20 to 24. The testing method involved assessing the pelvic position in the sagittal plane using the Duometer, which included evaluating pelvic position in the neutral position, maximum anteversion, maximum retroversion, as well as measuring body mass and height. Pelvic alignment in the sagittal plane was assessed based on angular values according to the Bibrowicz classification.

Results: Among the subjects, women presented correct pelvic alignment in all cases studied and fell within the normative values proposed by Bibrowicz. For men, only the maximum retroversion result fell within the normative range, while the other two measurements were below the proposed standards.

Conclusions: Pelvic alignment in the neutral position demonstrates greater angular values in the female group. Women also exhibited higher angular values in both maximum anterior tilt and posterior tilt. Pelvic alignment in individual positions in the study group, assessed based on angular values, tended to fall within the lower normative ranges determined by Bibrowicz. Exceptions were pelvic positioning in neutral and maximum anterior tilt in the male group.

KEYWORDS: pelvis, Duometer, pelvic alignment, sagittal plane, pelvic girdle

Background

The pelvis is a crucial part of the human skeletal system and plays an important role in movement, as body weight is transferred to the lower limbs via the pelvic girdle. It also supports the abdominal organs, which are sustained by both the pelvic floor muscles and the pelvis itself. As a result, the pelvis is central to many clinical problems of great significance today [1].

Pelvic movement is typically related to step width during human locomotion. This behaviour is often considered an important factor in bipedal stability [2]. During gait, the pelvis moves in three planes to enable smooth and efficient motion. Subtle sex-dependent differences in these movements may facilitate economical gait despite anatomical differences in pelvic structure [3].

For gait to be energy-efficient and to minimise the risk of injury, the pelvis should demonstrate proper development [4].

Posture formation begins during fetal life. In the womb, the infant's spine is in a flexed position with a single C-shaped curvature. The infant's pelvis is upright, and its forward tilt develops later with motor progression, upright posture adoption, and the for-

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mation of spinal curves. During the first year of life, the child gradually adapts to an upright posture. By the time upright posture is achieved, all spinal curvatures have formed, although their shape continues to undergo change [5].

The initiation of pelvic anteversion occurs during the second upright stage. The displacement of abdominal organs results in an increased abdominal girth. According to Kasperczyk, relationships between pelvic alignment and spinal curvature are not constant at first, and relative stabilisation appears around age 3. Significant trunk growth combined with relatively weak musculature contributes to constant modifications of spinal curvatures. Between ages 1 and 3, after the formation of cervical lordosis, thoracic kyphosis, and a defined lumbar lordosis, the pelvis shifts forward and tilts backward. At age 4, the pelvic tilt angle according to Wiles is approximately 22° (±2°). Between ages 7 and 10, due to starting school and prolonged sitting, the pelvic anteversion angle increases to around 25°. Sex differences also become evident. During adolescence (girls aged 15–18 years, boys aged 17–20 years), pelvic anteversion is greater in girls than in boys. In adults, it is approximately 28° in women and 31° in men, with variations of up to 4°, which are considered physiological [6].

In the Polish literature, the most commonly cited method for measuring pelvic tilt is that proposed by Wiles. However, English-language literature more frequently describes a method based on measuring the angle between a line passing through the anterior superior iliac spine and the posterior superior iliac spine in relation to the horizontal. Using these anatomical landmarks, we are able to assess maximum anterior and posterior pelvic tilt, as well as mobility during anterior and posterior rotation and the total sagittal-plane mobility range [7,8].

According to many researchers, diagnosis based solely on visual and palpation assessment has low reliability, creating a need for more precise testing methods. Using a device such as the Duometer eliminates visual estimation and standardises measurements compared with functional tests. The Duometer is a scaled anthropometric level equipped with an inclinometer and special measuring crossbars. Its measuring component is a miniature digital inclinometer with a resolution of 0.1°, and the device is characterized by high accuracy [7,8]. Normative ranges for pelvic alignment changes in young individuals without pain symptoms are presented in the table [8]. The adaptation of this tool for assessing pelvic alignment enables precise, quantitative measurement of asymmetries and deviations in the sagittal, frontal, and transverse planes. The innovative nature of this method lies in increasing the objectivity of posture assessment through a tool-based, repeatable, non-invasive measurement technique that enables monitoring of therapy progress and evaluation of physiotherapeutic or orthopaedic interventions.

Table 1. Suggested normative ranges for position and range of motion of pelvis in the sagittal [8]

Variable	Women (°)	Men (°)
Pelvic tilt	≥12≤20	≥12≤19
Anterior pelvic tilt	≥27≤38	≥26≤37
Posterior pelvic tilt	≥–1≤8	≥–1≤10
Anterior range of motion	≥12≤21	≥12≤21
Posterior range of motion	≥8≤16	≥6≤14
Total range of motion	≥22≤35	≥20≤31

Aim of the study

The study of pelvic alignment is a niche field within physiotherapy, as few scientific articles thoroughly describe the methods for its assessment. The aim of this study was to evaluate pelvic alignment in students using the Duometer. The pelvis was assessed in natural alignment, maximal posterior tilt, and maximal anterior tilt. This examination allowed for determining the range of pelvic mobility in the sagittal plane and identifying potential differences in pelvic alignment and mobility between men and women.

The following research questions were posed:

1. How is pelvic alignment shaped in the sagittal plane in its neutral position in men and women?
2. What are the angular values of pelvic positioning in maximal anterior tilt and maximal posterior tilt in men and women?
3. Do the angular values of pelvic positioning in the tested students fall within the normative ranges established for their age?

Material and methods

Material

Thirty students were examined, including 15 men and 15 women. Inclusion criteria were: consent to participate in the study, age between 20 and 24 years, and absence of known limb shortening or evident musculoskeletal disorders, particularly in the pelvis and spine. None of the participants reported involvement in competitive-level sports. Exclusion criteria were: lack of consent to participate, pelvic deformities, current limb shortening, or complete lack of physical activity. The somatic characteristics of the students are presented in Table 2.

Table 2. Characteristics of somatic features of the studied students

Somatic trait	Women		Men	
	Mean	SD	Mean	SD
Age (years)	22.13	0.74	22.6	0.74
Body height (cm)	167.00	5.68	179.67	5.18
Body weight (kg)	56.67	5.16	77.79	7.95
BMI Index	20.34	1.79	24.11	1.54

Methods

All measurements were carried out in accordance with the Declaration of Helsinki. The research project was approved by the Senate Committee for Research Ethics of the Wroclaw University of Health and Sport Sciences in 2001.

Methodology for measuring pelvic alignment in the sagittal plane using the Duometer

For the purposes of this study, a methodology for measuring the pelvic rim in the sagittal plane was applied. Pelvic alignment was assessed in the free position (FP), maximum forward tilt (MPF), and maximum backward tilt (MMT). The examination was conducted in a suitably prepared room, with adequate lighting, ensuring that the participant remained comfortable throughout the procedure.

The measurement in the sagittal plane was performed with the examiner seated sideways to the participant, who stood in a relaxed, upright position. The participant was barefoot, wearing underwear, and had the relevant bony landmarks (anterior superior iliac spines and posterior superior iliac spines) marked with a skin-safe marker. The examiner palpated the designated bone points using the fingertips and read the pelvic tilt angle from the inclinometer display. To assess maximal pelvic anteversion, the subject was instructed to perform maximum anterior pelvic tilt without bending the trunk or flexing the lower limbs. The maximal posterior tilt was assessed from the same starting position, but the subject was asked to maximally "raise" the pubic symphysis while contracting the gluteal and abdominal muscles [7,8].

Statistics

Excel was used to calculate the results of the study. Group descriptive statistics were employed to determine means and standard deviations for pelvic angles in each assessed position. These calculations were performed separately for men and women. The mean angular values were then compared with the normative ranges established by Bibrowicz. The results of the study are presented in Tables 3–5.

Results

Table 3 presents the results of angular pelvic alignment in the assessed positions for the female and male student groups. The data indicate that the mean pelvic alignment values were higher in women in all positions. The greatest difference was observed in the natural standing position, where men demonstrated values nearly 30% lower compared to women.

Table 3. Results of pelvic alignment measurements in the students studied

Pelvic position	Women		Men	
	Mean	SD	Mean	SD
FP (°)	12.5	3.31	7.78	3.29
MPF (°)	27.6	5.02	24.6	4.14
MMT (°)	4.38	2.61	3.17	2.82

FP – natural position; MPF – maximal pelvic foramen; MMT – maximal medial tilt.

Table 4 presents the magnitude of pelvic angular change from maximum anterior pelvic tilt to maximum posterior pelvic tilt in the two student groups. The data in the table indicate that the magnitude of angular change in pelvic position was greater in the female students. This result was approximately 8% higher compared to the male subjects.

Table 4. Size of angle change from MPF to MMT

Pelvic position	Women		Men	
	Mean	Average Change in angle from MPF to MMT (°)	Mean	Average Change in angle from MPF to MMT (°)
MPF (°)	27.60	23.22	24.60	21.43
MMT (°)	4.38		3.17	

Table 5 presents the mean pelvic angulation values in each position in both study groups (men and women), compared with the normative ranges proposed by Bibrowicz [7,8]. The data show that most parameters fell within the normative ranges. Only in the male group were the mean values of pelvic alignment in the neutral position and in the maximum anterior tilt position below the lower limit of the normative range. It can also be observed that the remaining pelvic alignment measurements tended

to fall near the lower limits of the normative ranges. This applied to both men and women.

Table 5. Comparison of the results obtained with the normative ranges proposed by Bibrowicz

Ustawienie miednicy	Kobiety		Mężczyźni	
	Średnia	Normy (°)	Średnia	Normy (°)
PS (°)	12.50	≥ 12 ≤ 20	7.78	≥ 12 ≤ 19
MPM (°)	27.60	≥ 27 ≤ 38	24.60	≥ 26 ≤ 37
MTM (°)	4.38	≥ –1 ≤ 8	3.17	≥ –1 ≤ 10

Discussion

The use of a duometer in assessing pelvic alignment is an innovative approach that brings a new quality to postural and biomechanical diagnostics. Until now, the duometer has been used mainly in measuring the angle of inclination of anatomical structures and in analysing joint mobility. The study of pelvic alignment is a niche area of physiotherapy, with much more emphasis on the study of the spine, lower limbs, or feet. Many papers discuss the assessment of posture in school-aged and adult children [9,10], in groups of athletes [11-13], elderly people [14-17], or the assessment of postural changes in the course of disease [18]. In this study, an attempt was made to assess pelvic alignment in the sagittal plane in a group of adult subjects. A novel Duometr device was used for the study, which allows assessment of body symmetry, lower limb valgus and varus valgus, the shape of the human spine, trunk asymmetry or measurement of hip mobility [19]. Its additional advantages are, the possibility of examining any patient, regardless of age, in virtually any conditions, as it is a lightweight, handy device - it can be easily carried.

The position of the pelvis in the sagittal plane is very much influenced by the muscles that have their attachments in this area. These are divided into muscle groups that increase or decrease anterior tilt [20]. The balance of muscle tension between these groups is very important, because if one group overpowers the other, spinal defects may occur. When increased tension occurs in the group responsible for the increased anterior tilt of the pelvis, a concave back may result. This defect is characterised by a protruding abdomen, causing the internal organs to move forward, which in turn causes a deepening of the lumbar lordosis. This positioning of the abdomen can significantly affect the function of the viscera. In this defect, we can mention muscles that are characterised by contracture and excessive tension. The iliac and lumbar muscles (the lumbar part) and the dorsal extensor (the part in the lumbar region) have a direct effect on increasing lumbar lordosis. Other muscles that also increase lumbar lordosis, but not directly (indirectly by increasing pelvic anteversion), are the iliac crest (hip part), rectus femoris and quadratus lumborum. The results of our study showed that female students had a greater pelvic angle in the neutral position than male students. This difference was nearly twofold. This may indicate a predominance of muscle tone that increases pelvic anteversion in women. This is also confirmed by a greater pelvic angle at maximum anteversion, but this difference between female and male students is no longer so great. In addition to this, the greater tension of the muscles responsible for the increased anterior tilt is also evidenced by the greater angle of pelvic positioning in maximum posterior tilt in women compared to the male group. The students were able to position their pelvises more vertically. The difference in the MTM parameter between women and men was close to 1.5°. Another plausible reason for the differences in pelvic alignment could be habits or customs attributed to the gender. Such a habit could be, for example, the wearing of high-heeled shoes by women. Long-term use of these shoes by women from puberty onwards is correlated with an increase in lumbar lordosis and pelvic anteversion. Studies conducted on this topic have revealed that with increasing duration of use of high-heeled shoes, both hyperlordosis and pelvic anterior tilt show increasing trends [21]. The results of our study did not examine the frequency of female students wearing such shoes; nevertheless, it can be assumed that such footwear was worn by them.

The alignment of the pelvis, and thus the spine, can also be influenced by a number of factors, ranging from anatomical structure to daily lifestyle and past trauma to the spine or pelvis. At the same time, changes in spinal curvature can affect the balance of muscle tone, as the body will compensate for abnormal spinal alignment with increased or decreased muscle tone in specific muscles.

Another factor that can affect pelvic alignment is lower limb shortening [22]. Before conducting pelvic alignment assessment studies, it is important to take into account whether the subject has a shortening of one of the limbs. In the group of students participating in our study, this factor was eliminated. In the future, however, studies could be designed to examine the extent to which the shortening of one of the lower limbs affects pelvic alignment.

Pelvic alignment is also negatively affected by incorrect ergonomics at work. This is often due to a lack of awareness among the public of how properly they should be seated. Putting one's leg over the other, putting the heel under the buttock - these are examples of positions that make sitting "more comfortable", but they are incorrect and can result in sacral pain [23]. At the same time, pelvic alignment and the balance of muscle tension are adversely affected, as

in some positions some muscles may be contracted and others stretched for long periods of time. Muscles positioned in one position for so long, adjust to this, and then when we even change our position they may tend to move towards this position, as it will be the most optimal for the length of the sarcomere in the muscle. This can lead to contractures of specific muscles within the pelvis, which will affect the pelvic alignment.

The results of our own study showed that the pelvic alignment in the various positions of the pelvis were within the normative ranges proposed by Bibrowicz [8]. It is noteworthy that these angles were rather close to the lower limits of these ranges. Only in the group of students did the pelvic position in neutral and maximum anterior tilt fall slightly below these ranges. This may be due to the specificity of the study group, and it may be worth extending such studies to a larger group of individuals.

Recent studies by Bibrowicz et al. show the potential of using the Duometer to assess pelvic symmetry. The studies showed that asymmetries in the pelvic region are common. They were observed in less than three quarters of the study population aged 19–29 [24].

The assessment of pelvic alignment in the sagittal plane is certainly worth supplementing with an assessment of its alignment in the frontal plane and with tests of the length or strength of the muscles responsible for its position in both planes. Research conducted by Bibrowicz et al. using a duometer and tensiomyography (TMG) did not reveal a clear correlation between pelvic tilt and the stiffness of muscles stabilising the lumbopelvic-hip complex [25]. This would give a more complete picture of the examination.

For the assessment of muscle strength, for example, the simple subjective Lovett method could be used, complemented by selected tests of muscle length in the pelvis or lower limbs. Such combined tests could be of great value in developing programmes for the prevention of musculoskeletal disorders of the pelvic region and spine .

CONCLUSIONS

Pelvic alignment in the neutral position demonstrated greater angular values in the female group.

Women also showed higher angular values both in maximum anterior tilt and posterior tilt.

Pelvic alignment in individual positions tended to fall within the lower normative ranges established by Bibrowicz. Exceptions were pelvic positioning in neutral and maximum anterior tilt in the male group.

The duometer, as a diagnostic tool for pelvic alignment, allows for accurate angular measurements and standardisation of test results.

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Corresponding author:
Arletta Hawrylak
Email: arletta.hawrylak@awf.wroc.pl
Council of the Faculty of Physiotherapy
Wroclaw University of Health and Sport Sciences
al. I. J. Paderewskiego 35 Street
51-612 Wrocław, Poland

Other authors/contact:
Katarzyna Barczyk-Pawelec
Email: katarzyna.barczyk-pawelec@awf.wroc.pl

Jacek Rydzyk
Email: rydzykjacek@gmail.com

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